

NCC2-1297

CmapTools: A Software Environment for Knowledge Modeling and Sharing

Final Report

Presented to: NASA Ames Research Center

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Executive Summary

In an ongoing collaborative effort between a group of NASA Ames scientists and researchers at the Institute for Human and Machine Cognition (IHMC) of the University of West Florida, a new version of CmapTools has been developed that enable scientists to construct knowledge models of their domain of expertise, share them with other scientists, make them available to anybody on the Internet with access to a Web browser, and peer-review other scientists' models. These software tools have been successfully used at NASA to build a large-scale multimedia on Mars¹ and in knowledge model on Habitability Assessment².

The new version of the software places emphasis on greater usability for experts constructing their own knowledge models, and support for the creation of large knowledge models with large number of supporting resources in the forms of images, videos, web pages, and other media. Additionally, the software currently allows scientists to cooperate with each other in the construction, sharing and criticizing of knowledge models. Scientists collaborating from remote distances, for example researchers at the Astrobiology Institute, can concurrently manipulate the knowledge models they are viewing without having to do this at a special videoconferencing facility.

Background

The CmapTools software environment, developed at IHMC, empowers users to construct, navigate, share, and criticize knowledge models represented as Concept Maps. The toolkit is platform independent and network enabled, allowing the users to build, and collaborate asynchronously during the construction of concept maps with colleagues anywhere on the network, as well as, share and navigate through others' models distributed on servers throughout Internet.

Concept Maps, developed by Joseph D. Novak (Novak & Gowin, 1984), is a two dimensional representation of a set of concepts and their relationships. In this representation, concepts are depicted as labeled nodes and relationships between

¹ The multimedia on Mars is available at <http://cmex.arc.nasa.gov>.

² The knowledge model on Habitability Assessment is available at http://65.212.118.153:8001/servlet/SBReadResourceServlet?rid=1060322529930_595980629_6699&partName=htmltext

concepts as labeled links. Concept maps represent meaningful relationships between concepts in the form of propositions: two or more concepts linked by words to form a semantic unit. Concept maps are designed to tap into a person's cognitive structure and externalize concepts and propositions.

Concept maps, unlike semantic networks, do not follow formal rules of syntax and semantics that enable a machine to do inferencing on the representation. They are meant to be a mechanism to share and communicate knowledge between humans – a mediating representation. We have extended the use of concept maps beyond knowledge representation, to serve as the browsing interface to a domain of knowledge. This concept map-based interface provides a unique way of organizing and browsing knowledge about any domain. Icons attached to the concept nodes provide access to auxiliary information to explain the concept in the form of pictures, images, audio-video clips, text, Internet links, etc. A couple of concept maps about Mars and associated resources are shown in Figure 1.

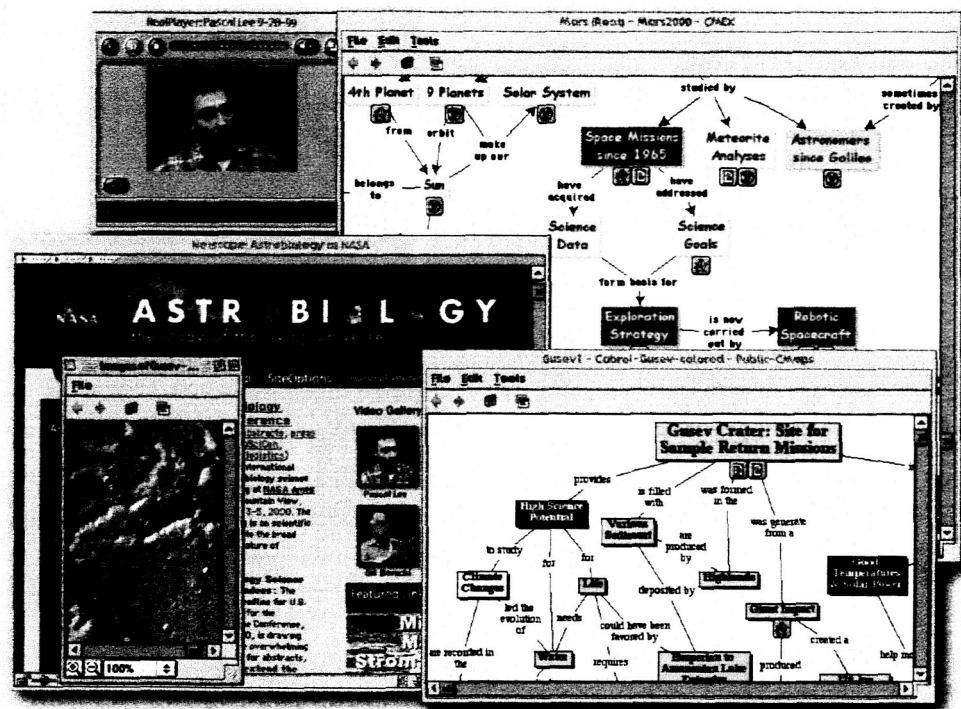


Figure 1: Concept Maps about Mars and associated resources

Through the concept mapping tools, it is easy for an expert to represent graphically his understanding of a domain of knowledge. At the same time, this

representation is straightforward to follow and understand by others, enabling sharing of expertise among scientists, professionals, etc. Through the aggregation and linking of knowledge models constructed by its experts, an organization can begin to capture and share its institutional knowledge.

The base tools provided support for asynchronous distributed scientific collaboration by allowing knowledge models to reside anywhere on the Internet, and be easily linked to other models. In addition, scientists can criticize or comment on each other's concept maps by initiating a discussion thread on any particular proposition of the map. Through a mechanism known as the Knowledge Soups (Cañas, Ford, Brennan, Reichherzer, & Hayes, 1995, July), scientists can also collaborate at the "knowledge level" (Newell, 1992), sharing and discussing propositions while constructing their own concept maps.

Proposed Research Objectives

The objectives of this work were to:

- (a) Support the construction of knowledge models for various NASA domains;
- (b) Develop a new version (v3) of the CmapTools software, based on the feedback obtained from the collaboration with NASA scientists with version 2, with enhanced support for scientists in the construction of knowledge models;
- (b) Develop synchronous collaboration tools that will enable scientists to work as a team real-time during the construction, sharing, and criticizing of knowledge models of their domain expertise and research.

Results

The research objectives were reached. In the next paragraphs we discuss each of the research objective points.

- (a) Two main knowledge models have been built at NASA based on the new version of the tools.

1. *Return to Mars*: The concept map-based multimedia on Mars created by the Center for Mars Exploration at NASA Ames has been expanded and converted to the format of the new v3 of the software. A version 3 CmapServer has been installed at NASA Ames Research Center to support this effort. A web page-based version of the atlas of Cmaps is available at <http://cmex.arc.nasa.gov>.

2. *Habitability Assessment:* The Habitability and Environmental Factors Office from Space and Life Sciences at NASA Johnson Space Center developed a collection of concept maps related to habitability. These maps take advantage of the latest features added to CmapTools. A web page-based version of the knowledge model can be accessed at http://65.212.118.153:8001/servlet/SBReadResourceServlet?rid=1060322529930_595980629_6699&partName=htmltext

(b) Version 3 of CmapTools was released on December of 2003, on time for the finalization of this grant. The software is available for download for free by educational and not-for profit organizations from <http://cmap.ihmc.us>. In the three months from December 18 to March 18, 2004 over 10,000 downloads of the program had been made by users from over 100 countries.

This new release of the software includes a large number of enhancements and new features, taking advantage of the experience and feedback gathered from working with NASA scientists. Among these features stand out:

1. *New Network Architecture:* The network architecture of CmapTools has been enhanced to further support collaboration and sharing among users and to provide indexing of all resources in the network. The discovery of services in the network is performed using the standard SLP protocol. The network consists of various types of servers:
 - a. *DirectoryOfPlaces:* The DirectoryOfPlaces allows the CmapTools client to locate services provided by CmapServers. Each CmapServer (and other servers such as the WebSearchServer, IndexServer and WordNetServer) periodically register with a DirectoryOfPlaces. By periodically (and automatically) contacting the DirectoryOfPlaces, the CmapTools program can find out what servers are available anywhere on the Internet.
 - b. *CmapServer: Services* -- The CmapServer enables users anywhere on the Internet to collaborate during the construction of their Cmaps, share the knowledge models they build, and browse, critique and comment on others' Cmaps. The CmapServer acts as a shared repository for Knowledge Models, Knowledge Soups, an index for searching for Cmaps and resources, enables collaboration through Discussion Threads and Synchronous Collaboration during Cmap editing, and automatically provides Web-page versions of the concept maps. Concept maps in a CmapServer can have links to

Cmaps and other types of resources on other CmapServers. The different functions offered on the CmapServer are implemented as services that can be discovered by the CmapTools client through broadcasting at the LAN or through the DirectoryOfPlaces.

- c. IndexServer:* All resources in CmapServers are indexed, and the resulting indexes copied to the IndexServer. Through the IndexServer, the Search function in the CmapTools client can locate resources throughout the whole network.
 - d. WebSearchServer:* The WebSearchServer provides web search services to the CmapTools client. The server receives queries, redirects them to Google or Yahoo, and ranks the result to match them to the contents of the concept map. In addition, the WebSearchServer provides a crawling function which further searches for web pages based on the contents of the queries it receives.
 - e. WordNet Server:* The WordNet server implements the WordNet (Miller, 1990) program as a server available to CmapTools client throughout Internet. This way, users have the functionality provided by WordNet (definition, thesaurus, etc.) without the need to have the full library installed in their computers.
- 2. *CmapTools Client:* A redesigned CmapTools client in v3 provides an easier to use environment for knowledge model construction. We discuss here some of the main features that distinguish it from the previous version.
 - a. Views:* A new user interface provides a hierarchical organization of folders, both at the user's computer (My Cmaps) as on shared servers (Places). Through drag-and-drop users can easily organize their knowledge models, copying them to servers for collaboration and sharing. Multiple windows of the Views' Places or Folders facilitate copying or moving resources between locations. The Views window includes tabs for "Favorites" (aliases to the bookmarked resources) and "History" (most-recently accessed resources).
 - b. Drag-and-drop:* Through drag-and-drop operations, users can import resources (images, videos, text, etc.) from the file system into the Views, and into the nodes of the concept maps, making it

extremely easy to construct knowledge models. The drag and drop is implemented across servers.

- c. *Right-click mouse button:* The right-click button of the mouse has been used to implement contextual menus for the different components of the concept maps.
- d. *Annotations:* An annotation tool has been added by which users can annotate each others' Cmaps.
- e. *Nested Nodes:* Groups of nodes (concepts and linking phrases) can be joined into a single element that can be expanded and shrinked, creating the capability of nested nodes.
- f. *Search capability:* Based on the IndexServer and the WebSearchServer discussed above, the search allows a user to search for resources and/or web pages that are related a particular concept map. Utilizing algorithms that try to determine "what the map is about", the program then searches for resources and web pages that are related to the map.
- g. *Dictionary and Thesaurus:* Utilizing the WordNet server discussed above, the program provides the function of searching for a concept or linking phrase in the WordNet database, and from there navigate through related words. To enhance the search, the program tries to determine the "sense" of the word within the concept map and present that sense as the first one on the WordNet dialogue box.
- h. *Publish:* For users who create large knowledge models on their My Cmaps, want to publish them to a server, but often make changes to the knowledge model, the Publish features allows the program to keep track of which resources have been modified, and only copy those resources to the server.
- i. *Import and Export:* The Import and Export functions have been enhanced to include tabbed-text, outline mode, Life Map and XML formats.
- j. *Style Palette:* A floating style palette provides all the style features needed to tailor a map, including the possibility of saving named styles.

- k. *Recorder*: A recorder module allows the stepwise reproduction of the construction of a concept map.
 - l. *Presentation*: The presentation module allows the user to control the order in which different pieces of a map are displayed on a full-screen, providing the capability of organizing presentations.
3. *Permissions*: A distributed permissions scheme has been implemented that gives the user complete control over the access to his/her knowledge models. Users can create userids+password combinations as needed and can provide read, write, delete and annotate permissions at the folder level. Inheritance in the evaluation of permissions makes it easy for users to set up different permission schemes depending on the needs.

(c) Synchronous Collaboration has been implemented in the tools. The mechanism is implemented to be completely intuitive for the user. If a user is editing a concept map that is stored in a server, and a second user tries to edit the same concept map, the system will tell the second user the concept map is being edited, and will ask him/her whether he/she wants to start a synchronous collaboration session. If this second user accepts, the first user is prompted, asking him/her whether he/she accepts a synchronous collaboration session with the second user. If he/she accepts, both users can now edit the map at the same time, with the results being shown on both screens concurrently. This mechanism works with all servers, and not tailoring is needed for it to work. More users can join the synchronous collaboration if so desired.

Summary

The objectives proposed for this research project have been attained. Features in version 3 of CmapTools far exceed the proposed implementation, and the number of downloads on the Internet is a good measure of its acceptance by users.

Publications

The following publications have been partially based on the work of this research: (A. J Cañas et al., 2003), (Cañas, Valerio, Lalinde-Pulido, Carvalho, & Arguedas, 2003), (Leake et al., 2003), (Cañas, Carvalho, & Arguedas, 2002), (González & Cañas, 2003), (Cañas, Hill, Lott, & Suri, 2003), (Cañas, Hill, & Lott, 2003), (Cañas, Carvajal, Carff, & Hill, 2004), (Coffey et al., 2003), (Coffey, Hoffman, Cañas, & Ford, 2002), (A. J. Cañas, C. Zea et al., 2003), (Hoffman et al., 2002), (Leake, Maguitman, & Cañas, 2002).

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